CORN PRODUCTION

Ministry of
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ONTARIO

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Growth and Development

Germination and Seedling Development

If corn seed is planted in soil that is warm and moist enough, it will begin to germinate soon after planting. Germination begins with the seed absorbing soil moisture equal to about 30% of the weight of the seed. The first external sign of germination is the appearance of the "radicle" near the tip of the kernel. Under favorable conditions, this may occur within 2 or 3 days after planting. The first roots of the seedling develop from the radicle. Shortly after the appearance of the radicle, the shoot emerges and begins to grow towards the soil surface. The tip of the shoot is protected by a needle-like leaf called the "coleoptile". Because it is pointed and stiff, the coleoptile is able to penetrate through the soil without damage to the leaves inside. Once the coleoptile is exposed to light, it stops growing and splits open allowing the leaves to emerge.

If the seed is planted too deep, or if growing conditions are unfavorable, the coleoptile may open underground. This could also be caused by damage from insects, diseases or some herbicides. Because the exposed leaves are soft, they are unable to push through the soil. The result is reduced emergence and/or badly distorted plants (Figure 1).

In warm (18 to 20° C), moist soil, corn seedlings can emerge in as few as 5 days. In cooler soil (10 to 12° C), emergence can take up to 3 weeks. Germination and emergence do not occur at soil temperatures below 10° C. Corn seedlings are very susceptible to disease organisms and insects during this early stage of growth, especially in cold soil. Application of a seed treatment containing suitable fungicides and insecticides is very important to ensure uniform emergence of healthy seedlings.

Figure 1. Seeds that leaf out underground indicate that planting was too deep and/or crusting was a problem

Vegetative Development

Once the seedling is established, the plant creates a root system, stalk and leaves which will later support grain production. Leaves are produced at the growing point which remains below the soil surface for the first 3 or 4 weeks following emergence. All the leaves are formed by the time the seedling reaches the 5- to 6-leaf stage. After this stage, the increase in plant size is the result of elongation of the stalk and expansion of the existing leaves. The number of leaves per plant varies from year to year and among hybrids. Longer-season hybrids generally have more leaves than short-season varieties. Also, above-normal soil and air temperatures 2 or 3 weeks after emergence will result in the production of more leaves. Consequently, late-planted corn is often taller and leafier than early-planted corn, but total dry matter production is reduced.

Tassel and Ear Development

Shortly after all the leaves have been produced, the tassel and ears are initiated. By the time the corn is knee-high, the miniature tassel can be found inside the stem just above ground level. Over the next several weeks, the tassel is pushed upwards as the stem elongates. Most of the growth of the tassel itself occurs in a rapid burst a few days prior to its emergence from the whorl of leaves.

Ears are initiated at several nodes along the growing point (a node is the point at which the leaf sheath is attached to the stalk). Usually, only one ear develops. Generally, this ear is located 6 to 8 nodes below the tassel. Occasionally, if the stand of corn is thin, a second ear will develop at the node below the main ear. Rudiments of an ear may also be visible at several other nodes, but these rarely develop.

As the corn plant nears its full height, the ear and tassel grow rapidly. The 2 weeks preceding the shedding of pollen represent a very critical period in the determination of the potential size of the ear. The number of ovules (kernels) that will produce silks is determined during this period. Adverse growing conditions, such as drought, nutrient deficiency, flooding, herbicide damage, or very high temperatures can limit the number of ovules formed. Since the upper limit of grain yield is set by the number of kernels initiated, losses caused at this time cannot be completely compensated for by good conditions later on.

Flowering

Pollen shed normally begins 2 to 3 days after the tassel has fully emerged from the whorl. Shedding of pollen continues intermittently for several days. Pollen is not released if the tassel is too wet or too dry. Thus, there is no danger of the pollen being washed away by rain.

The silks usually emerge from the ear and are pollinated within 4 to 10 days after tassel emergence. When a pollen grain lands on a silk, the pollen germinates to produce a "pollen tube" which must grow down the entire length of the silk before fertilization can occur.

The period surrounding flowering is the most critical in determining yield. Under hot, dry conditions, the silks dry out and may not be able to support growth of the pollen tube. Moisture stress can also delay silking. In extreme drought, the silks may not emerge until after pollen shed has been completed. In either case, the result is incomplete seed set and reduced yields.

This period represents a peak in demand for all growth factors. The corn plant is devoting nearly all of its energies into producing an ear. If the plant is under too much stress, it is unable to supply enough materials to support all the developing kernels. Even kernels which have been fertilized may abort during the first few days following fertilization. Stress caused by drought, disease, insects, nutrient deficiency (especially nitrogen), over-population, or even several days of cloudy weather can reduce yields.

Grain Filling

Soon after pollination, a period of rapid accumulation of grain dry matter begins, lasting for 30 to 40 days. Grain filling continues for several more days thereafter, but at a decreasing rate. Kernels are usually completely filled within 50 to 60 days after silking. The achievement of maximum grain dry weight can be detected by observing the formation of a distinct black layer at the base of the kernel. Usually this occurs when the moisture content of the grain is 31 to 35%. However, black layer formation can occur at much higher moisture contents if kernel development is stopped prematurely by frost or disease.

The moisture content of the kernel decreases throughout the grain filling process. Prior to black layer formation, most of this decrease in moisture content occurs as water in the kernel is replaced by starch. This is a relatively rapid process. After black layer formation, drying occurs more slowly as moisture is evaporated from the surface of the kernel. Thus, corn which stopped filling prematurely is much slower to dry than is corn which matures normally.

In Ontario, maximum whole-plant dry weight is usually reached when the grain moisture content is about 45 percent. Maximum corn silage yields can be obtained by harvesting at this stage. This is roughly one to two weeks prior to the achievement of maximum grain dry weight. At the end of the grain filling period, the increase in kernel weight results from the transfer of carbohydrates from the stalk to the grain. Therefore, silage feeding value remains constant over this period, although the moisture content decreases.

The advance of grain maturity can be traced by following the progress of the "milk line" in the kernels. When the kernels have dented pick an ear and break it in two. The exposed face of the upper end of the ear will reveal the smooth surface of the kernels. The milk line should be visible near the top of the kernels. This line represents the boundary between the solid, starchy portion of the kernel and the milky, lower part. As the grain matures, the line moves downward towards the tip of the kernel. When the milk line is halfway down the kernel, the grain moisture content will be about 40%. The line will disappear at the tip of the kernel shortly before black layer formation, giving a good indication of when the crop is about to reach physiological maturity.

Climate and Soil

The main climatic factors important to corn production are temperature and rainfall. Corn takes up and evaporates through its leaves about 350 liters of water for every kilogram of dry matter that is produced. The amount and distribution of rainfall in Ontario is generally suitable for good corn production. However, problems arise each year in specific areas where rainfall pattern influences corn yields. Moisture stress is the greater problem on coarse-textured (sandy) soils, while excess moisture is a more common problem on fine-textured, compacted or imperfectly-drained soils.

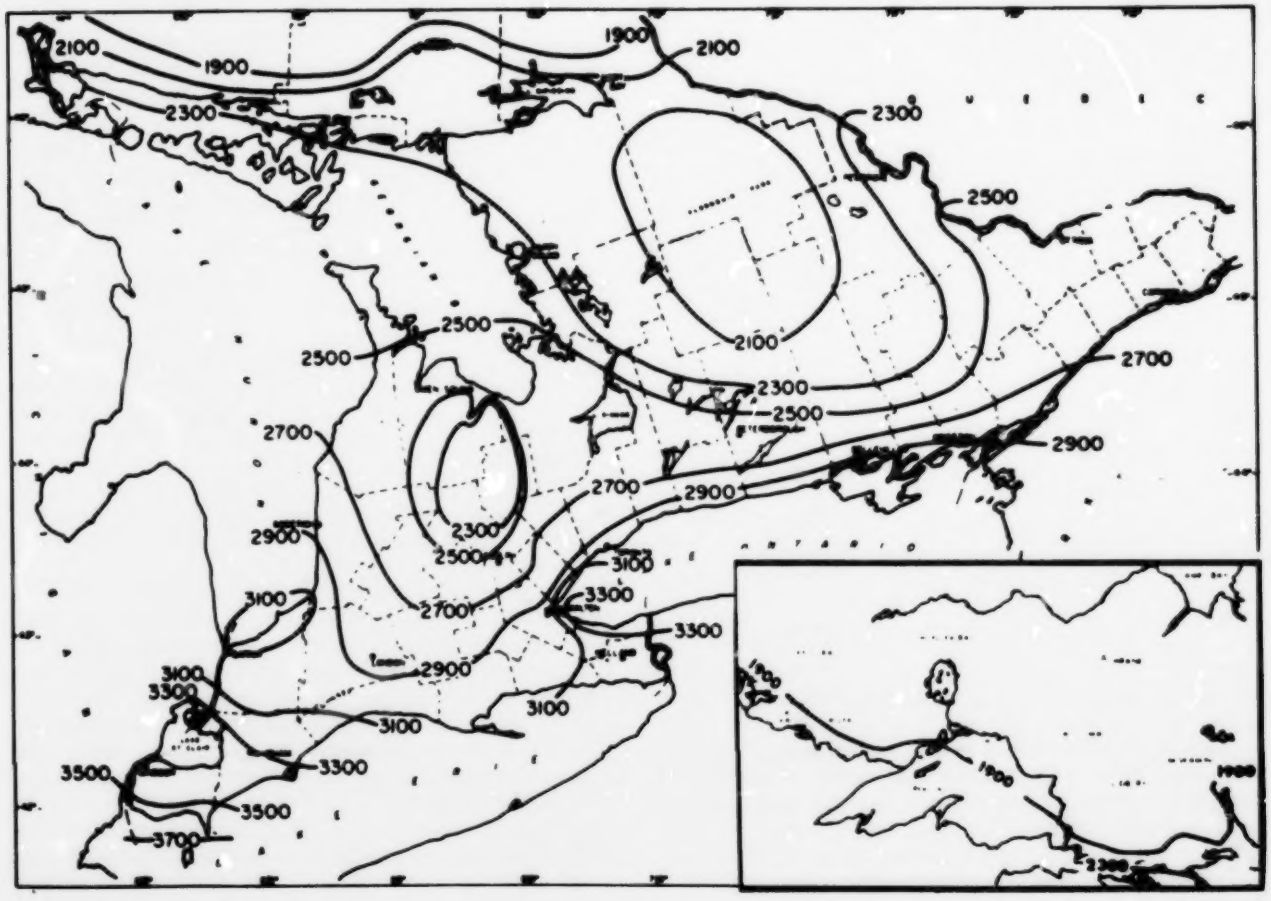

Figure 2. Heat units available for corn production in Ontario

Temperature is the main climatic factor influencing where corn can be produced in Ontario. Large areas of the province do not have sufficient heat to mature corn. Corn hybrids are rated for the amount of heat required to bring the crop to maturity according to the Ontario corn heat unit system. Heat unit values are based on the daily maximum and minimum temperatures, since the rate of plant development varies with temperature. Figure 2 indicates the number of heat units available for growing corn throughout Ontario. Grain corn can be grown in areas with 2400 or more heat units, while corn for whole-plant silage can be produced in areas with as few as 2200 heat units. More information on the Ontario corn heat unit system can be found in the OMAF Factsheet, *Heat Units for Corn in Southern Ontario*, Agdex 111/31.

Corn hybrids have also been rated according to a "Day System". This system was developed in Minnesota and is an indication of the length of time hybrids take to mature in that state. It can be used as a relative comparison of hybrid maturity but is not an indication of the actual number of days required for a hybrid to reach maturity in Ontario. For example, a hybrid rated at 80 days usually takes between 120 and 130 days to mature depending on growing conditions. The heat unit system is a more reliable way of describing hybrid maturity because the number of heat units required for maturity remains relatively constant from year-to-year. The number of days required to reach maturity can vary widely depending on location and growing conditions. Because of this, there is no precise conversion factor to compare heat unit ratings with maturity day ratings. However, Table 1 gives an approximate comparison of the two systems.

Table 1. Hybrid Maturity Rating Systems — Ontario Heat Units and Relative Maturity Days

Ontario Corn Heat Units	Relative Maturity Days
2400	75
2500	78
2600	82
2700	85
2800	89
2900	93
3000	97
3100	100
3200	104
3300	107
3400	110

Corn can do well on most soil types with proper management. Soil structure and drainage are more important factors than is soil texture. Corn does not perform well on compacted, droughty or poorly-drained soils.

The soils throughout Ontario vary considerably in fertility. However, with very few exceptions, a suitable fertilizer program can be developed for corn production.

Choosing A Hybrid

One of the most critical decisions in growing corn is that of hybrid selection. Corn hybrids differ greatly in their performance with each one having specific strengths and weaknesses. Choosing the wrong hybrid could mean the difference between making a profit or a loss.

Grain

Each year, the Ontario Corn Committee conducts a series of trials throughout southern Ontario to evaluate hybrids for grain yield, maturity and standability. The results are published each December in the *Ontario Hybrid Corn Performance Trials Report.* This report can be a valuable guide in choosing corn hybrids.

The first consideration in choosing a hybrid must be the ability of the hybrid to reach the proper stage of maturity before frost in the fall. Hybrids that mature too late produce low yields and wet, poor-quality grain. Late maturity also means that harvesting will take place when the risk of adverse weather is greater.

The yield of hybrids that mature too early may be reduced because part of the growing season is wasted. However, planting an early hybrid does allow harvesting to begin earlier, and may allow part of the crop to be sold at old crop prices.

Locate the vicinity of your farm on the map in Figure 2 and estimate the number of heat units available. Since the number of heat units received will also be influenced by the slope, elevation and soil type, the actual heat units received by a farm, over the long-term, may vary from the estimate by up to 50 heat units. Once you have established the heat unit rating for your farm, select hybrids requiring that number of heat units or less. This should ensure that corn planted by mid-May will reach full maturity before a killing frost nine years out of ten.

If planting is delayed beyond mid-May, reduce your estimate of the number of heat units available by 100 for each week that planting is delayed. For example, in a 2900 heat unit area, if planting is delayed to May 24, select a hybrid that requires no more than 2800 heat units to mature.

One can also advance the date of maturity in the fall by selecting hybrids requiring fewer heat units. Again the advance in maturity is about one week for every 100 heat units that the hybrid rating is reduced.

Once the maturity range is established, the final selection must be based on yield and standability. Both factors should be given equal consideration. A high-yielding crop is of little value if it is severely lodged.

The goal should be to choose a hybrid that consistently produces an acceptable yield while standing well. To some extent one must compromise between maximum yield potential and standability. During the final stages of grain filling, reserves of carbohydrates stored in the stalk are moved into the grain. Once this source of energy is gone, the stalk dies and becomes susceptible to stalk rot organisms. The larger and more demanding the ear is, the quicker this occurs. Some hybrids gain a high yield potential at the expense of stalk strength. They always attempt to produce a large ear by draining the stalk of all its reserves. Under good growing conditions, the stalk may contain enough carbohydrates to fill a large ear while maintaining stalk strength. However, if conditions have been stressful, reserves

in the stalk will be low and will be depleted quickly. The result will be premature death of the stalk and severe lodging. Thus, these hybrids produce exceptionally high yields under good growing conditions, but go down badly under poor conditions.

The most consistent hybrids are often those that appear to have just an average yield in the Corn Performance Trials. They produce and fill moderately-sized ears while leaving some reserve energy in the stalk. Thus, they can produce acceptable yields while maintaining good standability even under stressful conditions.

Because the effect of growing conditions on yield and standability is so great, it is important to use data that has been collected over a range of environments. In the Performance Trials Report, most hybrids appear in at least two tables. Study all the data on hybrids that you are considering. Consider results from other sources as well. Select hybrids that yield and stand consistently well wherever they are tested.

Hybrids on the recommended list are designated as either single cross, three-way cross, double cross or other cross. This refers to the way in which the hybrid is produced from inbreds. There is some difference in seed prices among the various types of hybrids. However, this should be a minor consideration in choosing a hybrid. The best approach is to base hybrid selection on performance not on hybrid type.

Many of the very early-maturing hybrids are known as flint-dent crosses. These are usually the result of crossing North American "dent" material with European "flint" material to obtain earliness. Flint and flint-dent hybrids produce kernels which have a hard, rounded shape without a dent (similar to that of popcorn). Flint-dent hybrids are early in maturity, but their grain is slow to dry because of the harder nature of the kernel. Fortunately, this hardness also allows these hybrids to be harvested at higher moisture contents than dent corn. This can be a significant advantage when growing corn in short-season areas. Flint-dent corn is best used as livestock feed because the flint type of kernel is undesirable in many industrial uses of corn.

Silage Corn

Experience has demonstrated that hybrids producing high grain yields also produce good silage yields. When choosing hybrids specifically for whole-plant silage, a yield advantage can usually be obtained by selecting hybrids rated 100 to 200 heat units later than those selected for grain.

Tillage and Rotation

Traditionally, most corn land in Ontario has been prepared for planting by moldboard plowing followed by a number of secondary tillage operations. In recent years conservation tillage systems have become more popular.

In the past, tillage was required for three main purposes: (a) weed control; (b) burial of residue from the previous crop; and (c) preparation of a satisfactory seedbed.

Since the late 1950's chemical herbicides have reduced the need for tillage in a weed control program. However, some chemicals need to be incorporated into the soil and some weed escapes may need to be controlled by inter-row cultivation.

Burial of crop residue is becoming less important. Many newer corn planters are designed to operate despite trash on the soil surface. Residue left on the soil surface can be beneficial since it helps hold the snow in winter and assists in reducing soil loss from runoff.

The most important reason for tillage is to prepare a seedbed. For this purpose secondary tillage does not need to be deeper than 5 to 7 cm.

Tillage does affect yield but the response varies significantly with soil texture. No tillage treatments have been found that produce higher yields than the traditional combination of fall moldboard plowing, followed by secondary tillage. However, other systems are frequently use to reduce cost and/or soil erosion.

Corn planted with zero-tillage following corn has averaged about 15% lower yield than with conventional tillage in most situations. On sandy and gravelly loams or where corn has followed crops other than corn, yield differences caused by zero-tillage have been smaller.

Corn yields with chisel plowing have been similar to those following moldboard plowing on sandy loam soils, but not on silt loam, clay loam or clay soils (Table 2). However, where corn is grown following crops other than corn on fine-textured soils, chisel plowing has resulted in yields similar to those after moldboard plowing.

Table 2. Long-term effects of three tillage systems on corn grain yields when corn was grown continuously.

Tillage Treatment	Grain Yield (t/ha) Silt loam	Clay loam
Fall moldboard plow, spring secondary	6.76	6.94
Fall disk-chisel plow, spring secondary	6.33	6.39
Zero tillage	5.86	6.07

Corn fits well into a wide range of crop rotations. Corn grown in rotation with other crops will be more productive than corn grown continuously. In some instances continuous corn has led to problems with weeds, insects and diseases. In other cases, continuous corn has resulted in poorer soil structure which in turn has led to compaction, poor drainage, greater energy inputs to till the land, crusting, erosion, and ultimately reduced yield.

Corn in rotation with other row crops, such as soybeans and field beans, is an improvement over continuous corn but soil structure problems may not be corrected. Cereal and forage crops help to offset some of the detrimental aspects associated with growing row crops.

Planting

Seeding Date and Planting Depth

The best yields are usually obtained from corn planted in the first half of May because the crop is able to use the full growing season. Early planting also results in earlier maturity in the fall, reducing the risk of damage from an early fall frost or adverse weather at harvest. The optimum planting date is around May 7 in southwestern Ontario and May 15 in central and eastern Ontario. Delaying planting past the optimum date can result in yield reductions averaging 40 kg/ha per day of delay.

It is advisable to start planting slightly before the optimum date. Take advantage of good conditions when they occur.

The risk of a yield reduction from planting a bit too early is less than that from planting too late. Although corn leaves can easily be frozen in the spring, corn is rarely killed by spring frosts. The growing point of corn generally remains below ground until the danger of frost is over. When planting early or in cold soil, place the seeds 2 to 3 cm deep, where the soil will be warmest. Deeper planting will result in delayed emergence and uneven stands.

When planting in warm soil, the seeding depth generally should be such that the seed is placed in moist soil. Excessively deep planting should be avoided. Seeds planted more than 7 cm deep may have difficulty emerging, especially on fine-textured or compacted soils where crusting may be a problem.

Row Width

No yield advantage has been found for row widths narrower than 90 cm in southwestern Ontario or 75 cm in central and eastern Ontario.

Plant Populations

When planting early in the season or when the soil is cold, a seeding rate 10% higher than the desired final stand is recommended. When soils are warmer, an adjustment of 5% is sufficient.

In Ontario, corn has commonly been grown at populations of 52,000 to 58,000 plants per hectare. (The plant populations discussed here are suggested final plant stands.) These populations will produce good yields over a wide range of growing conditions. In recent years, some hybrids have been developed which tolerate higher plant densities without excessive lodging or barrenness. Under good growing conditions, higher yields can be obtained from these hybrids using plant populations up to 67,000 plants per hectare.

Under good growing conditions, an increased plant population results in higher yields because of the increased number of ears per unit of land. However, increased plant density also places plants under more stress through interplant competition for light, moisture and nutrients. This results in smaller ears, more barren plants, thinner stalks and increased stalk breakage. If the population is pushed too high, these factors combine to cause a yield reduction and higher harvest losses.

Increased plant densities are not appropriate for all situations because of the many factors that interact with plant population to place the crop under stress. Factors such as drought, weeds, insects, diseases, soil compaction, inadequate fertility and poor drainage all serve to exaggerate the stressful effects of increased plant populations. The more severe these stresses are, the lower the optimum plant population.

Yield increases from increased plant densities have been least in areas with 3000 heat units or more. In these areas, optimum plant populations will be 5000 to 7000 plants per hectare lower than those discussed below. This difference is caused by many factors including larger plant size and higher temperatures at silking.

Hybrid selection is a critical factor in determining the optimum plant population. Many hybrids yield well at 55,000 plants per hectare, but cannot tolerate higher densities, especially if growing conditions are less than ideal. Only a few hybrids can tolerate a population of 67,000 plants per hectare and respond by producing a higher yield. The population selected must be suitable for the hybrid being grown and the growing conditions likely to be encountered. It may be necessary to change the plant population when changing hybrids or fields.

Experience with previous corn crops can provide guidelines for choosing a plant population. Final stands as low as 50,000 plants per hectare should be considered on soils low in fertility, susceptible to drought, imperfectly drained, or otherwise in poor condition.

An increase in plant density is most likely to result in improved grain yield in fields that already have a history of high yields with little lodging. These will be fertile, well-drained fields with good moisture-holding capacity. There appears to be little advantage to plant densities over 67,000 plants per hectare for grain corn.

The benefit from higher plant densities will most likely be obtained when corn is planted early. Later plantings result in larger, leafier plants and more inter-plant competition. Late-planted corn will also silk later when the risk of drought or heat-stress is greater. Therefore, plant density should be reduced as planting is delayed.

Because lodging is of less concern with corn grown for whole-plant silage, higher plant populations can be used than for grain corn. In areas with less than 3100 heat units, final stands of 60,000 to 70,000 plants per hectare will produce higher silage yields with little effect on the grain content or moisture level of the silage. These populations should be used only where it is certain that the field will be harvested for whole-plant silage. Fields left for grain at these densities could lodge excessively. Even for silage, the population should not exceed 60,000 plants per hectare on soils that are droughty or otherwise in poor condition.

Seed Treatment

Seed corn sold in Ontario is treated with a fungicide to protect the seed against decay organisms. An insecticide may also have been added to control insects that attack seed in storage. At planting, additional insecticide should be added to the seed to give protection from soil insects such as wireworms and seed maggots. For seed treatment recommendations, consult OMAF Publication 296, *Field Crop Recommendations.*

Seed Quality

Canada has an effective Seeds Act and inspectors of Agriculture Canada monitor seed quality. In addition, companies have seed quality control programs. Farmers should, therefore, encounter few problems with vigor and germination level of corn seed. However, if emergence problems occur it may be necessary to check the quality of the seed involved. Tags on each bag of seed corn indicate the germination level, the date it was tested and the seedlot from which it was obtained. Unless these tags are saved it is impossible to identify the seedlot that was sown. Therefore it is also impossible to re-check the quality of the seed if a problem arises. A set of tags from each seedlot along with a small sample of seed should be saved to assist in tracing the cause of such problems.

It would be wise to check the germination of carry-over seed before planting. One approach is to place 100 kernels of seed between wet paper towels. The towels should be kept

moist and at room temperature. At the end of a week, the number of kernels with healthy sprouts represents percent germination. A more reliable test involves planting the seed in a flat of soil. This test should be conducted at a lower temperature (12 to 15° C). A cool basement or back kitchen may be suitable. The number of healthy plants that emerge within two weeks represents percent emergence. Planting rate should be increased to compensate for reduced emergence.

Corn Planter Calibration

Regardless of the type of planter, it is of great importance to check and adjust its performance ahead of time, so that corn planting can proceed with confidence as soon as soil and climatic conditions permit. Calibration can be divided into a number of steps.

1. Make Sure that the Planter is in Good Condition

Check all moving parts on the planter for wear, breakage, loose-fitting sprockets and gears etc. This task is much easier if the planter is cleaned of all dust, dirt, grease, seed treatment and rust. Tighten any loose nuts and bolts. In the case of a plate-type planter, make sure that the cutoff and knockout pawls are not worn, are moving freely and have adequate springs. Hopper bottom plates should be checked, and replaced if worn.

Where a finger-type plateless planter is used, all parts should be checked over as above. Fingers should be checked for freedom of movement and thoroughly cleaned. Fingers should not be oiled. A dry lubricant such as graphite is added to the seed for lubrication of the finger mechanism.

If a drum-type air-planter is used, a further check is needed to ensure that the hopper, metering drum and seed tubes are airtight, and that all seals and gaskets are in good condition. Cutoff wheels should turn freely; they and the brush should be free from damage. Check fan bearings and drive belts for wear.

With a unit-type air or vacuum-planter, fans, hoses and electrical connections should be checked for leaks, wear and dirt. Fans should be run and operating pressure checked.

2. Seed-Plate Sizing

Seed corn is graded according to size in three directions — length, width and depth. A great range of seed-plates is available to match these dimensions. Plates can be checked on a test stand at the seed company or machinery dealers. Use a sample of your own seed and thoroughly clean old plates. Cell fill should be slightly over 100% to ensure that even the largest kernel in the sample will be planted. In other words, a 16-cell plate should deliver slightly more than 16 kernels per turn, on average.

The faster the planting speed the harder it is for a kernel to find its way into every cell. Most manufacturers recommend using oversize cells at higher planting speeds.
One manufacturer's recommendations are:

Planting speed of 5.5 km/h — cells 1/64" oversize in length and width

Planting speed of 7 km/h — cells 1/32" oversize in length and width

Planting speed of 8.5 km/h — cells 1/16" oversize in length and width

If a seed treatment is to be used at planting time, it may affect planter performance. Treated seed should be used when calibrating.

3. Adjust Planter for the Required Planting Rate

The corn planter Operator's Manual carries a chart to enable the user to select the correct drive wheel and hopper shaft sprockets to give the required spacing between the kernels. Table 3 shows the spacing between the seeds within the row for specific seeding rates at various row widths.

Where pneumatic-tired drive wheels are used, it is important to be sure that these are of the recommended size and the right pressure.

4. Calibrate in a Laneway or Gravel Area

Planting accuracy may be affected by planting speed and other field factors. For this reason, a calibration run should be carried out at full planting speed, over an area where the kernels can easily be found and counted. A laneway or gravel area is very suitable for this. The seed treatment that is to be used in actual planting should also be used for this calibration run.

Using two stakes mark off a distance on the laneway or gravel area. Table 4 shows the distances to give an area equivalent to 1/2000 of a hectare per row, for various row widths.

Using a wire or string, engage the planter drive clutch so that the planter will operate with the openers raised. Remember to reset the clutch afterwards. Half-fill the hoppers with seed corn.

The planter should be moving at full planting speed before it reaches the first stake. Continue at full speed past the second stake and then slow down and stop.

After the calibration run, count the kernels dropped in each row over the measured distance. This will show if any single unit is defective, as well as giving a check on overall seeding rate. To find the number of kernels per hectare, multiply the number of kernels dropped per row over the measured distance by 2000.

The seeding rate should be somewhat higher than required in the field, because drive wheel slippage will be less on the gravel surface than it would be in the field. If the actual number of kernels dropped in the calibration run differs from the required number by more than a few hundred kernels per hectare check that the planter is set properly, and that all units are operating correctly. If there are no faults, either a different plate or a different drive setting is required.

Where the seed is ejected from the planter by a blast of air, the above method is not satisfactory. Seed can be collected by tying cloth bags on the end of the seed tubes, and driving exactly the marked distance.

5. Field Check During and After Planting

After step 4, the planter should be calibrated correctly. However, to be completely certain that unusual field conditions are not interfering with planting accuracy, uncover a few lengths of row soon after planting begins and check the distance between kernels. If the average spacing is not the same as that required, the planter can be further adjusted.

Because emergence can be variable it is advisable to check the plant population during the growing season.

Table 3. Centimetres Between Seeds to Achieve Specific Seeding Rates

Seeds per hectare[1]	Row Width[2] — Centimetres (Inches) 76 (30)	81 (32)	86 (34)	91 (36)	97 (38)	102 (40)
44,000	30	29	26	25	23	22
49,500	26	25	23	22	21	20
55,000	24	22	21	20	19	18
60,500	22	20	19	18	17	16
66,000	20	19	17	16	15	15
71,500	18	17	16	15	14	14
77,000	17	16	15	14	13	13

[1] *1 hectare = 2.47 acres*
[2] *1 centimetre = 0.39 inches*

Table 4. Distances to Measure for Planter Calibration or for Checking Plant Populations (meters).

Distance to travel for:	Row Width[2] — Centimetres (inches) 76 (30)	81 (32)	86 (34)	91 (36)	97 (38)	102 (40)
1/2000 hectare[1]	6.58	6.17	5.81	5.49	5.15	4.90

[1] *Hectare = 2.47 acres*
[2] *Centimetre = 0.39 inches*

Placing the seeds at uniform spacing within the row is relatively unimportant. Corn can tolerate large variability in seed spacing. Yield is not significantly affected by gaps as long as the proper seeding rate is delivered. Planting of "doubles" (two seeds per hill) also does not greatly affect yield as long as the population is kept constant. Thus uniformity of seed spacing is not a major consideration when choosing a corn planter. All types of planters, when set properly, space seeds uniformly enough that yield is not affected.

When to Replant

Poor seed quality, cool weather, wireworms, seed corn maggots, seed rots, deep seed placement, herbicide damage, fertilizer burn or extremes in soil moisture content can all result in reduced emergence. With poor emergence, the question of replanting arises.

A very significant reduction in stand is needed before replanting can be justified. The yield potential of replanted corn will be reduced because of the later planting date. There also will be additional costs for tillage, seed, planting and perhaps chemicals. Replanting corn will usually be less profitable than accepting the reduced stand if it is over 40,000 plants per hectare. Even at lower populations, replanting is not always advisable. Replanting should be undertaken only after carefully weighing the costs against any potential gain.

Fertility

Providing adequate fertility is an essential step in producing a profitable corn crop. Because crops can obtain nutrients from the reserve in the soil the fertilizer does not have to supply the crop's total requirement. Since nutrients supplied by the soil are essentially free-of-charge, fertilizer application rates should be selected to supply only that portion of crop nutrient requirements which cannot be obtained from the soil. The ability of soil to supply nutrients varies greatly, depending on soil type and field history. The regular use of a reliable soil testing service is essential to plan a profitable fertilization program.

To provide dependable fertilizer recommendations each field should be tested at least once every third year. When large amounts of nutrients are removed from sandy soils (with crops such as alfalfa or corn silage) annual testing is recommended since soil potassium levels can change rapidly.

Nutrients Required by Corn

The soil supplies 13 nutrient elements that are required by corn for proper growth (Table 5). Most of these elements are not required in fertilizer because their levels in Ontario soils are sufficient to meet crop requirements. Most corn growers need to consider only nitrogen, phosphorous and potassium when planning their fertilizer program, although deficiencies of zinc or magnesium are sometimes encountered.

Table 5. Nutrient concentrations in corn (Mid-third ear leaf sampled at silking)

Element	Critical Minimum[1] (%)	Normal Maximum[2] (%)
Nitrogen	2.5	3.5
Phosphorous	0.15	0.5
Potassium	1.2	2.5
Calcium	*	1.5
Magnesium	0.10	0.6
Sulphur	0.14	*
	(ppm)	(ppm)
Boron	2	25
Copper	2	20
Manganese	15	150
Zinc	12	70
Iron	10	*
Chlorine	*	*
Molybdenum	*	*

* *Deficiencies and/or toxicities of some elements have not been demonstrated on Ontario soils.*
[1] *Yield loss due to nutrient deficiency is expected if nutrient concentrations are at or below the "critical" level.*
[2] *Normal maximum concentrations are more than adequate but do not necessarily cause toxicities.*

Nitrogen

Nitrogen is required for the proper growth and development of the entire corn plant. A lack of nitrogen results in stunted yellow plants (Figure 3), reduced yields, delayed maturity and increased lodging. Excessive nitrogen can result in reduced yields, and increased lodging. Extreme levels

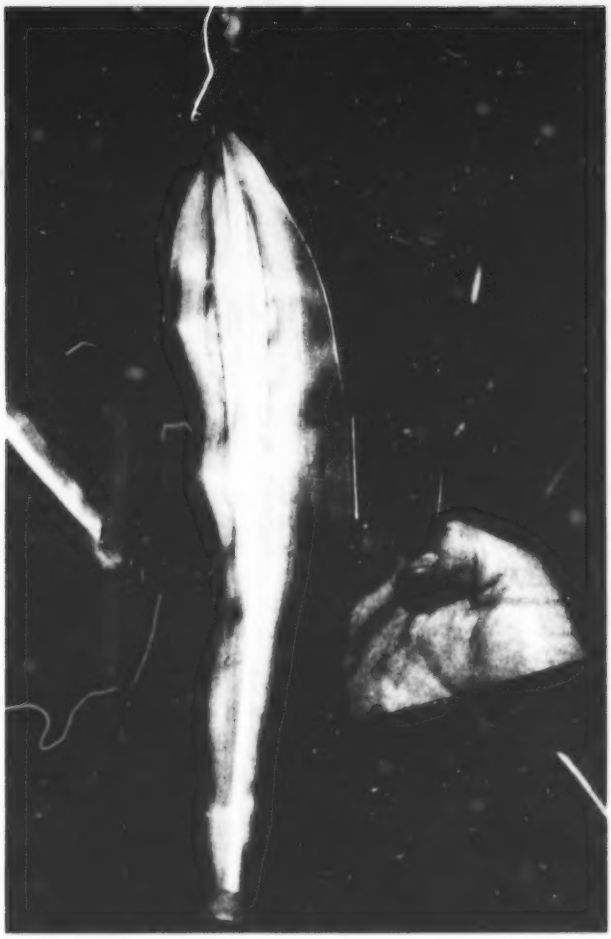

Figure 3. Nitrogen deficiency

can result in nitrate accumulation in the stalk which may lead to production of silo gas. Therefore, it is important that nitrogen application rates be appropriate for the yield expected.

Because of the complexity of the nitrogen cycle in soil, no reliable test has been found to measure the ability of soil to supply nitrogen in Ontario. Recommendations for nitrogen are based on a standard application rate with adjustments for soil texture, manure usage, crop rotation, time of application and expected yield. Current recommendations and adjustment factors for nitrogen rates can be found in OMAF Publication 296, *Field Crop Recommendations.*

Several forms of nitrogen fertilizer are available for use in corn (Table 6). When applied properly these forms are equally effective in supplying nitrogen to the crop. Other considerations such as cost, safety, convenience, timing, and compatability with herbicides will influence the decision of which nitrogen source to use. (Refer to OMAF Factsheets, *Nitrogen Recommendations for Corn,* Agdex 111/541 and *Nitrogen Fertilizer Materials* Agdex 111/542.)

Table 6. Nitrogen sources for corn

	% Nitrogen
Anhydrous ammonia	82
Aqua-ammonia	20
Urea	45
Ammonium nitrate	34
Non-pressure solutions (U.A.N.)	28 or 32
Pressure solutions	41

Nitrogen should be applied in the spring (fall application of nitrogen is not recommended because a large proportion of it is lost over the winter). A small amount of nitrogen should be applied in a band through the planter. The major portion of the nitrogen requirement should be applied either preplant or as a side-dressed application. Side-dressed nitrogen should be applied before the corn is 30 cm high.

Under wet conditions, nitrogen is subject to being lost from heavy soils through a process called denitrification (soil bacteria convert nitrates to nitrogen gas which is lost to the atmosphere). This effect is most pronounced with preplant applications in southwestern Ontario. In Essex, Kent and Lambton Counties and on the clay and clay loam soils of Huron, Perth, Middlesex and Elgin, preplant applications of nitrogen have not been as efficient as side-dressed applications. Nitrogen requirements should be increased by 30 kg/ha for preplant applications on these soils. Also in this area, anhydrous ammonia has been slightly more efficient than urea or ammonium nitrate.

In the rest of Ontario, preplant application is equal to side-dressing and there has been no yield advantage for ammonia over urea or ammonium nitrate.

Solid forms of nitrogen and U.A.N. solutions can be applied to the bare soil surface without incorporation. However, urea or U.A.N. applied on crop residues should be incorporated immediately to avoid losses (an enzyme in residues converts urea to ammonia which is lost to the atmosphere). Under dry conditions the effectiveness of all forms of nitrogen will be improved by incorporation.

Care must be taken if nitrogen solutions are applied post-emergence. If the fertilizer solution contacts leaves, severe burning and yield reductions are likely to occur.

Anhydrous ammonia, applied with conventional equipment, should be placed at least 15 cm deep in the soil. When appropriate equipment is used, ammonia may be applied with a disc or cultivator a minimum of 10 cm deep, provided that outlets are spaced no more than 50 cm apart.

For preplant applications of anhydrous ammonia, outlets should be spaced no more than 50 cm apart to reduce the chance of injury to the seed. If wider spacings are used delay planting 4 days after application.

Phosphorus

Phosphorus (or phosphate) is required for plant growth and development throughout the life of the plant, but is critical for proper seed development. Phosphorus supply is also critical early in the growing season (Figure 4). Young seedlings require a high concentration of phosphorus, but have difficulty in obtaining it because of their small root system and the slow release of phosphorus from cool soil. Application of a small amount of phosphorus near the seed over-

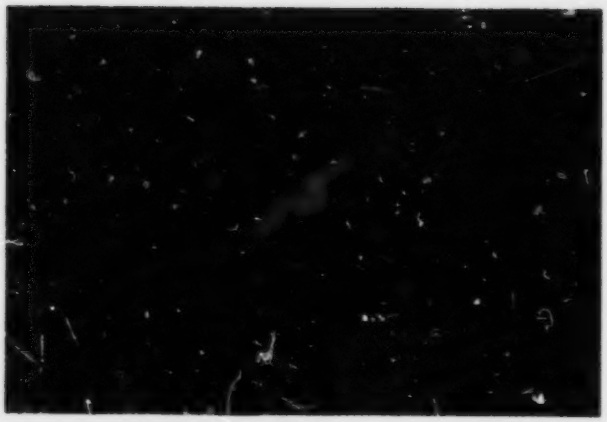

Figure 4. Phosphorus deficiency

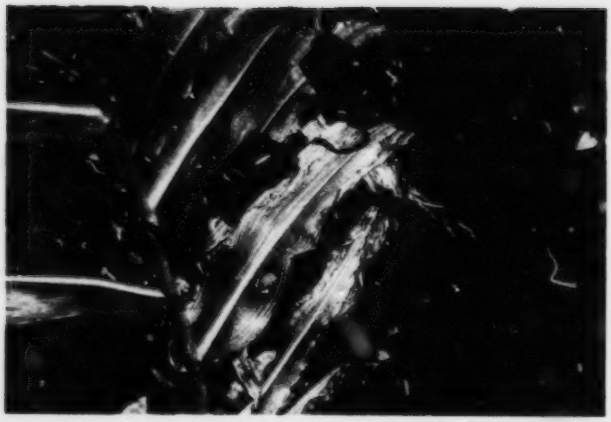

Figure 5. Potassium deficiency

comes this problem and results in more vigorous growth of the corn seedling. This is often referred to as a "starter effect", and can be obtained from as little as 5 to 10 kg/ha of actual phosphate placed near the seed.

A soil test is the only reliable way to determine phosphorus requirements. Where phosphorus is required some should be banded near the seed at planting because broadcast fertilizer does not give a starter effect. At low requirements, all of the phosphorus can be applied at planting. Where large amounts of phosphorus are needed, it may be more convenient to broadcast most of it, although a small amount should still be applied through the planter. On soils where no phosphorus is recommended, a starter fertilizer will improve early growth and may advance crop maturity, but is unlikely to increase yields.

Phosphorus is usually supplied from mono-ammonium phosphate (12.5-50-0), diammonium phosphate (18-46-0) or triple super phosphate (0-46-0). The phosphorus in all of these materials is readily available to plants. However, when the fertilizer is to be banded near the seed, the plant will make more efficient use of the phosphorus if nitrogen is also included in the fertilizer mixture.

Potassium

Potassium (or potash) fulfills many roles in the corn plant and influences yield, grain quality and lodging (Figure 5). Clay and clay loam soils often contain enough potash to meet corn requirements for many years without fertilization. Sandy soils are poor suppliers of potassium and can be depleted within a few years if underfertilized. Regular soil testing is essential to select a profitable rate of fertilization and to ensure that soil potassium levels are maintained at adequate levels.

Nearly all of the potassium used in corn fertilizers is obtained from muriate of potash (0-0-60). Where potassium is required some should be included in the starter fertilizer. Where a large amount of potash is needed, most of it should be broadcast to avoid damage to the seed. Potash is equally effective when broadcast either in the fall before plowing or in the spring before seedbed preparation.

Fertilizer Burn

Too much fertilizer put near the seed can cause damage and reduce emergence because of the "burning" effect of the nitrogen and potassium in the fertilizer. Most planters are set to place the fertilizer 5 cm to the side and 5 cm below the seed. At this spacing the starter fertilizer should not contain more than 55 kg/ha of actual nitrogen or more than a total of 90 kg/ha of actual nitrogen plus potash. Safe rates for other types of application are found in the soil management section of OMAF Publication 296, *Field Crop Recommendations.*

Liquid Fertilizers

Liquid fertilizer formulations are available that permit placement of a small amount of fertilizer in direct contact with the seed (this placement can increase the risk of crop injury if dry conditions persist after planting).

The nutrients in liquid fertilizers are equal in availability and crop response to those in dry fertilizers. Liquid formulations offer benefits in terms of convenience of handling, but are often more expensive than dry fertilizers in terms of the cost per unit of nutrient applied.

Acid Soils and Magnesium Deficiency

Soils tend to become more acidic as a natural result of crop production. When corn is grown this trend is accelerated with the use of relatively large amounts of nitrogen fertilizer.

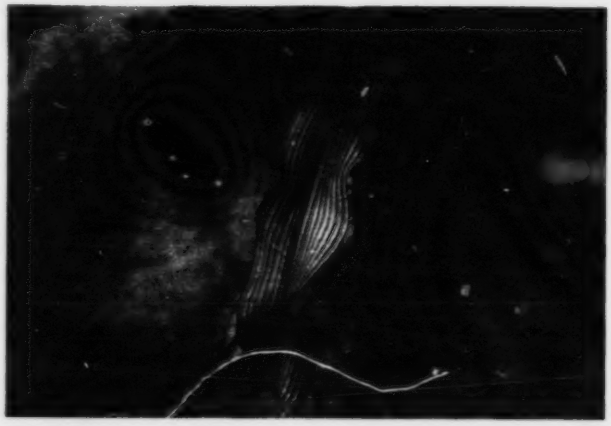

Figure 6. Magnesium deficiency

Sandy soils in particular become acidic if continuous corn is grown. Corn requires a soil pH greater than 5.5 for proper growth. Acid soils should be limed according to recommendations based on a reliable soil test. On acid sandy soils, corn often exhibits magnesium deficiency with striping along the length of the lower leaves (Figure 6). Acid soils which are low in magnesium should be limed with dolomitic limestone to correct both the acidity and the magnesium deficiency. Where magnesium is not a problem, either calcitic or dolomitic lime can be used. (Refer to OMAF Factsheet, *Soil Acidity and Liming*, Agdex 534.)

Magnesium deficiency can also be induced by over-application of potassium. Where soil levels of magnesium are marginal, apply only enough potassium to meet current crop requirements as indicated by a soil test.

Few soils that do not need lime will require magnesium. Magnesium application is recommended only if the magnesium soil test is less than 20. On these soils magnesium can be supplied either by magnesium sulphate or, if potassium is also required, by sulphate of potash magnesia. Apply 30 kg/ha of water soluble magnesium.

Zinc

Zinc deficiency is most noticeable when corn is in the four-to-six-leaf stage (Figure 7). It usually appears as broad, light-colored strips on either side of the midrib of the younger leaves. Zinc deficiency is common in spots where erosion or deep plowing has brought subsoil to the surface. Symptoms are most pronounced under cool conditions because release of zinc from the soil is slowed. If the deficiency is slight, corn often recovers without adverse effects once the soil warms up. In more severe cases maturity is delayed and yields may be reduced.

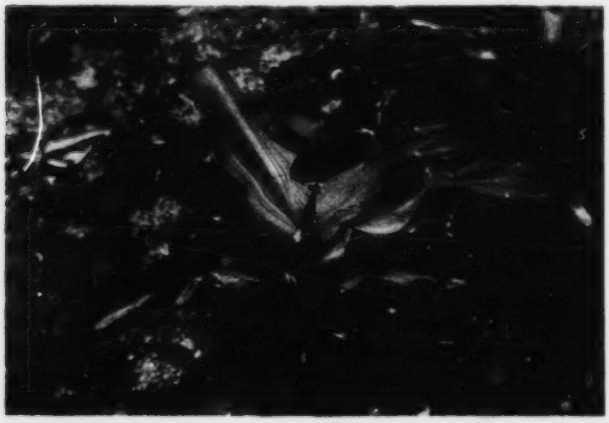

Figure 7. Zinc deficiency

Zinc deficiency can also be induced by over-application of phosphorus. This effect is especially noticeable with phosphorus applied in a band at planting. On soils prone to zinc deficiency, application of phosphate through the planter should be kept as small as possible. If a large amount of phosphate is required, most of it should be broadcast.

Profitable responses to applications of zinc are rare if phosphorus fertilization is managed properly. Where it is necessary, zinc can be applied either as a foliar spray or included in the mixed fertilizer. Recommendations can be found in OMAF Factsheet, *Zinc Requirements for Field Crops*, Agdex 100/531.

Manure

Livestock manures contain large amounts of available nutrients. If managed carefully, manures can supply most of the nutrients required to grow a crop of corn. Manure can also help improve soil structure because of its high organic matter content.

Because the nutrient content of manure varies greatly, it should be analyzed. Current information on manure analysis and recommended application rates are given in the soil management section of OMAF Publication 296, *Field Crop Recommendations*.

Manure use is not without its problems. Manure must be stored and applied properly to reduce nutrient losses and to eliminate the risk of water pollution. Manure-spreading equipment can cause severe soil compaction if used on moist soils. Thus, it can be difficult to time manure application to take advantage of its fertility without causing soil compaction.

Continual use of manure at high rates can cause some nutrients to build up in the soil to excessively high levels. It may also increase soil organic matter levels to the point where the performance of soil-applied herbicides is adversely affected. Regular testing of the soil and manure will help in selecting a suitable application rate. Manure is a valuable resource, but its use must be managed carefully if its full value is to be realized without damaging the soil or the environment.

Nitrogen from Legumes

When sod containing perennial legumes, such as alfalfa, red clover or bird's-foot trefoil, is plowed under, it supplies a large amount of nitrogen to the following crop. A sod that is more than half legumes can often provide enough nitrogen to meet the entire requirement for a crop of corn the following year. A plow-down crop of red clover can supply up to 45 kg/ha of nitrogen. Current adjustments in nitrogen requirements following sod are found in OMAF Publication 296, *Field Crop Recommendations*.

Weed Control in Corn

Adequate weed control is essential for profitable corn production. Even a light infestation of weeds can reduce yields by 10 to 15%. Severe infestations can reduce yields by 50% or more. Weeds compete with the crop for light, water and nutrients, and can harbor insects and diseases injurious to the corn. Weeds can create harvesting problems and increased harvest loss.

Ideally, weeds should be controlled for the full season. However, the most critical period for weed control is usually the first six to eight weeks after crop emergence. The potential size of the ear is determined over a three-week period starting about six weeks after emergence. Competition from weeds during this period irreversibly reduces the potential for good yields.

Many herbicides are available for use in corn. When used in a properly managed weed control program, these chemicals can control most commonly encountered weed species. Herbicides are available for preplant incorporated, preemergence, or postemergence applications. Thus, it is possible to select a herbicide program to fit most corn production systems. Current weed control recommendations are found in OMAF Publication 75, *Guide to Chemical Weed Control*.

Because of the wide range of weeds controlled by herbicides used in corn, the corn crop has often been used to "clean up" a field. (For example, the use of atrazine in corn is still one of the most effective ways to eliminate quack grass.) However, the continual use of this small group of herbicides has caused a change in weed populations to weeds that are not completely controlled by atrazine. There is also an increasing number of "new" weed species that are resistant to or escape from herbicide programs currently in use.

These problem weeds are forcing a change in weed control strategy. Proper weed identification is an essential first step. Some weeds are susceptible to only one herbicide so it is critical that the herbicide program be matched carefully with the weeds present. Since some weeds are not completely controlled by soil-applied herbicides, other weed control measures become necessary. Some weed species are best controlled with postemergent herbicides. For others, a timely cultivation can eliminate most of the escaping weeds. Even hand-pulling or hoeing can be very valuable when dealing with small infestations. Crop rotation is also useful. The herbicides used in other crops will control some weeds that cannot be controlled in corn and differences in crop competition and life cycles will help prevent weeds from maturing.

While it may not be possible to completely avoid the introduction of new weeds, one can slow their spread. Farm machinery — the combine in particular — is a major means of spreading weed seeds. If possible, fields that are known to be infested with problem weeds should be harvested last to avoid spreading the weed into "clean" fields. If custom-combining is used, areas that are combined first should be watched closely for the appearance of new weeds the following year.

Seeds of some species are able to pass through livestock and remain viable in the manure. Thus, weed seeds can be introduced or spread via grain corn, corn silage, or other livestock feeds. Careful observation and prompt action while the infestation is still small offer the best defense against future problems.

Information on specific problem weeds can be found in a series of OMAF Factsheets as listed under References.

Corn Diseases

Many diseases can affect corn in Ontario. Some of the more important ones are discussed here.

Stalk Rots

Stalk rots are the most destructive group of corn diseases in Ontario. Stalk rots cause the interior of the stalks to become discolored and to disintegrate (Figure 8). Thus, the stalks are severely weakened and become very susceptible to breakage.

Stalk rot is caused by several fungal organisms including Fusarium, Diplodia, Pythium and Gibberella. These organisms are present in all fields. They attack dead or dying plant tissue and help rot down crop residues. In this sense, they play a very valuable role in nature.

Most stalk rots are unable to significantly affect healthy plants. During most of the growing season, while the stalks contain a high level of carbohydrates, corn plants are able to resist the stalk rot organisms. However, as grain filling depletes the reserves in the stalks, they become more susceptible to infection. Stalk rots are generally diseases of "old age", occurring late in the grain filling period and when the grain is drying down in the field.

Figure 8. Stalk rots (healthy stalk, second from right)

Poor growing conditions can cause the carbohydrate reserves in the stalks to be depleted prematurely. This can result in earlier infection by stalk rots and more severe lodging. Increased lodging can be expected where the crop was under stress because of low fertility, drought, over population, soil compaction, prolonged cloudy weather, etc. Also, any factor which reduces leaf area (such as hail, early frost, leaf diseases or insects) will increase the likelihood of lodging.

Hybrids differ greatly in their ability to tolerate stress and/or stalk rots. Selection of hybrids with superior standability is the best way to overcome the adverse effects of stalk rots. It is also important to use cultural practices that minimize the amount of stress imposed on the crop.

Ear and Kernel Rots (Ear Molds)

Several organisms can attack the ear and kernels causing mold. Two of the more common are Fusarium moniliforme and Gibberella zeae. Fusarium usually invades the ear around wounds caused by insects such as corn borer, corn earworm or corn rootworm adults. Initially it causes a pink to reddish-brown discoloration of the caps of the kernels. As the disease develops, a cottony pink mold growth develops (Figure 9). Gibberella infection occurs through the silk (development of the disease is favored by cool, wet weather within three weeks after silking). It produces a reddish mold which usually starts to develop at the tip of the ear. Badly infected ears may rot completely with the husks sticking tightly to the grain.

Fusarium and Gibberella also cause stalk rots and are present in most corn fields. Because they overwinter on residue from the previous corn crop, the incidence of ear mold is much higher in continuous corn than that grown in rotation. The incidence of ear molds is increased by high plant population, high rates of nitrogen and use of late maturing hybrids. Hybrids with ears that hang downward at maturity appear to develop less ear mold than those with ears that remain upright.

Figure 9. Ear mold

Grain must be dried thoroughly to ensure that molds do not continue to develop in storage. Shelled corn should be dried below 15% moisture. In cribs, molds can continue to develop at ear moisture contents above 18 to 20%. In high moisture storage, mold growth is arrested by the ensiling process.

Ears infected with Gibberella may contain zearalenone which can cause breeding problems in swine and vomitoxin which can cause reduced feed intake. Although growth of these molds stops when the grain is dried or ensiled, the toxins remain. Because mold may be present on the ear without producing toxin, on-farm feeding trials or laboratory analysis are the only reliable methods of determining the suitability of moldy corn for use in hog rations. The laboratory analysis is available through the OMAF Veterinary Services Laboratory located at the University of Guelph.

Eyespot

Eyespot is a leaf disease that is common throughout Ontario. It is characterized by numerous small (2 mm) spots with cream or tan colored centers surrounded by a dark brown or purple ring and a yellow halo (Figure 10). Each spot has the appearance of a small eye. Heavy infections of eyespot can seriously affect yields and standability because of the reduction in leaf area. Hybrids vary greatly in their susceptibility to this disease with some hybrids being extremely susceptible.

Figure 10. Eyespot

The fungus that causes eyespot overwinters on crop residues and is spread by rainsplash and wind. The first infection occurs on the lower leaves, but in wet weather the disease can be spread to the upper leaves and husks. The incidence of eyespot is often highest under reduced tillage systems where much of the crop residue is left on the soil surface.

Anthracnose

Anthracnose was first identified in Ontario in the early 1980's. It has become an important disease in the United States and may increase in importance in Ontario. Anthracnose has leaf disease and stalk rot phases, both of which have been found in Ontario.

The anthracnose fungus overwinters on infected residues from the previous corn crop. Thus, this disease may be more prevalent in reduced tillage situations. In the spring, spores are produced which infect the lower leaves. On the leaves, anthracnose produces oval spots, up to 15 mm in diameter, with tan centers and reddish-brown or yellowish-brown margins (Figure 11). These spots initially resemble those produced by eyespot but become much larger. Infection occurs first on the lower leaves, but can spread to the upper leaves under wet conditions. Infected leaves wither and die prematurely late in the season or during prolonged wet weather.

The stalk rot phase usually develops after tasselling. The interior of an infected stalk becomes water-soaked and may disintegrate completely. This disease results in severe lodging and may cause premature death of the rest of the plant. Anthracnose can be distinguished from other stalk rots by the presence of large, shiny, black blotches on the surface of the stalk near ground level (Figure 12).

Control of anthracnose involves crop rotation and the use of hybrids that are specifically resistant to the anthracnose form of stalk rot. Resistance to other stalk rot organisms does not appear to provide any resistance to anthracnose.

Figure 11. Anthracnose — leaf phase

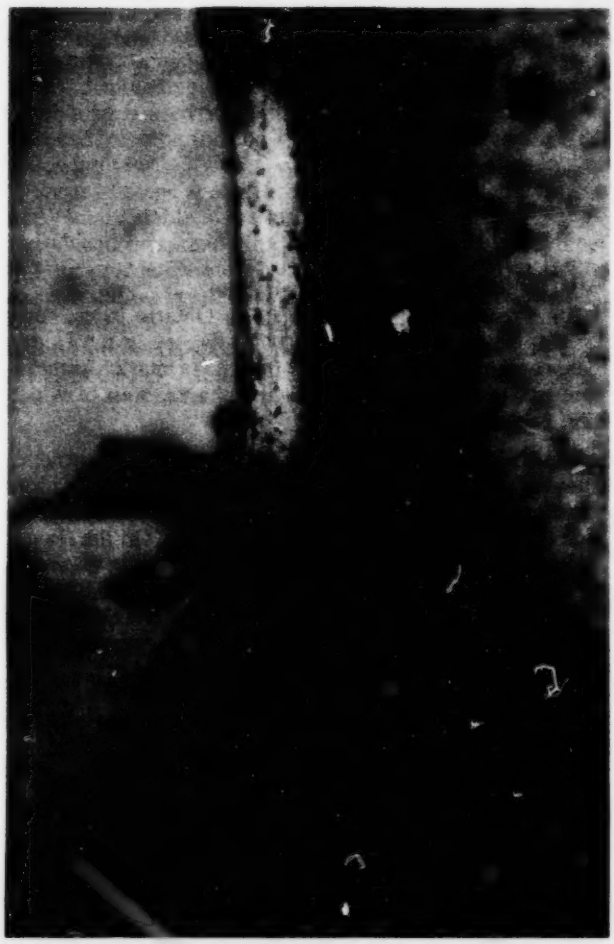

Figure 12. Anthracnose — stalk rot phase

Figure 13. Common smut

Common Smut

Common smut can be identified by the formation of large greyish galls which may reach 10 cm in diameter (Figure 13). These masses form on the stalk, ear or tassel. Smaller galls may also be formed on the leaves. When the fungus matures, the galls release black spores which transmit the disease to other plants. Infection occurs where the plant cells are rapidly growing or where the tissue has been injured by hail, blowing sand, herbicide damage or cultivation. Excessive rates of nitrogen can also increase the incidence of common smut.

Most corn hybrids have enough resistance to common smut to prevent serious infestations, although some smut is present in most fields.

Head Smut

Head smut spores overwinter in the soil. In the spring, the head smut fungus enters the corn seedling at the time of germination and emergence and develops systematically within the plant. Corn under stress during emergence appears to be more susceptible to infection. The highest incidence of head smut is usually on compacted headlands, in wet areas or in late-planted corn.

Symptoms of the disease do not become apparent until the tassel and ears develop. The cobs of infected plants are usually replaced by a mass of black spores enclosed completely by the husks. Grain is almost never present on infected ears. Head smut may also affect the tassel causing it to look like a black sooty brush (Figure 14). Where the tassel is affected by head smut, the ear will also be infected. However, other plants may have infected ears without the tassels being affected.

Head smut was first identified in Ontario in 1979 and was found on about 100 farms in 1980. Since then, there have been no serious outbreaks of this disease although minor infestations are found every year. Corn hybrids with good resistance to head smut are available.

Figure 14. Head smut — infected tassel

Northern Leaf Blight

Northern leaf blight is a leaf disease that produces long, oval spots that may reach 15 cm in length (Figure 15). Development of this disease is favored by warm temperatures and heavy dews. Severe infections may cover almost all of the leaf, causing infected leaves to die permaturely. Susceptible hybrids can suffer substantial yield reductions if northern leaf blight becomes established before silking. Most hybrids possess adequate resistance to this disease.

Figure 15. Northern leaf blight

Rust

Rust is present throughout Ontario. It produces many small golden-brown blisters on corn leaves. As the disease progresses these spots split open releasing the characteristic powdery, rust-colored spores (Figure 16). Because this disease is favored by cool, damp weather, it usually does not develop until late in the growing season and is relatively minor. In addition, most modern hybrids have adequate resistance to rust.

Figure 16. Rust

Crazy Top

This disease is of little economic importance in Ontario but arouses considerable attention when it occurs because of the peculiar appearance of infected plants. Crazy top is caused by a systemic infection of downy mildew. Infection occurs when the soil is flooded for 24 to 48 hours between planting and the 4 to 5 leaf stage. Infected plants are stunted, crooked and produce abundant tillers. The tassel is often replaced by a mass of twisted, leafy tillers. Provision of adequate drainage offers the best means of control.

Insects in Corn

Several species of insects can cause damage to corn. The following descriptions give a brief outline of the appearance, life cycle and damage caused by some of the more common corn insects. For recommendations on control, consult the current edition of OMAF Publication 296, *Field Crop Recommendations.* Information on several insects can be found in the series of OMAF Factsheets listed under "References" at the back of this publication.

Wireworms

The adult of the wireworm, called a click beetle, usually lays its eggs in grassy areas. Old pastures are often heavily infested. The wireworms that hatch from these eggs are thin, straw-colored larvae that may reach 4 mm in length (Figure 17). They feeds on the roots of the grass or any crop that may have been planted in the field. Wireworms most often attack the germinating seeds destroying the seedlings before emergence. However, this insect may also feed on the roots and lower stems of emerged plants causing them to wilt and die.

The wireworm requires 2 to 5 years to complete its life cycle. Crop damage is often the most severe in the second crop year following grassy sod. The wireworms feed on the remains of the sod during the first year, but in the second year, the crop seedlings provide the only source of food.

Seed treatments containing an insecticide offer some protection to the seed against this insect. However, seed treatments give little protection to the plant after emergence. Some of the insecticides used to control corn rootworm larvae also control wireworms.

Figure 17. Wireworms

Seedcorn Maggot

The seedcorn maggot is a small whitish larva that reaches a maximum size of about 7 mm (Figure 18). These maggots attack both the seed and lower stems of seedlings resulting in poor emergence or weak, dying seedlings.

The adult of the seedcorn maggot is a small fly which lays its eggs in the soil. It is attracted to areas with a high organic matter content such as muck soils or fields that have been heavily manured. Because this insect develops relatively late in the spring, late-planted corn is especially susceptible. Seed treatments containing an insecticide can protect the seed from moderate infestations of seedcorn maggots. Early planting, use of good quality seed and any other factors which encourage fast emergence will also reduce the likelihood of damage from this insect.

Figure 18. Seed corn maggots (in soybean seed)

Slugs

Slugs are not insects. They are mollusks, related to snails and clams. They feed on the lower leaves of plants, particularly in the tender areas between the veins. This causes the damaged leaves to look split or shredded (Figure 19). Slugs feed at night, and are often difficult to find during the day. One indicator of their presence is the shiny "slime trails" left behind on the soil surface. The slugs may be found resting in moist areas under stones, lumps of soil or crop residues.

Figure 19. Slug damage

Slugs die if they dry out. Therefore, they usually reach damaging numbers only during periods of prolonged wet weather or where abundant crop residue keeps the soil surface moist. Damage occurs most commonly following a forage or plowdown crop, especially in fields that were spring-plowed. Because of the crop residues on the soil surface, slugs may also be more prevalent in fields where minimum tillage systems are used. At present, there is no recommended means of chemical control for slugs in field corn.

Armyworms

Armyworms are brown or dark green caterpillars with five stripes running the length of their back (Figure 20). When fully grown, they will reach a length of 4 to 5 cm. Armyworms feed on the leaves of grassy plants including corn. The first sign of damage will be a few gouges in the edges of the leaves. In severe infestations, the leaves may be completely eaten except for the midribs.

Figure 20. Armyworm larva

The adult of the armyworm is a light-brown moth that is active only at night. Eggs are laid during June in thick grassy growth. Therefore, armyworms are more commonly a problem in fields if grassy weeds are not controlled properly. They may also move into corn fields from fencerows or adjacent fields.

If gouging of the leaves is evident, the field should be checked for the presence of armyworms. Because they feed at night, the best time to check is in the late evening or early morning. During the day, armyworms hide under lumps of soil, in clumps of grass, or within the whorls of the corn plants. Five or six larvae in an area 30 cm by 30 cm is sufficient to justify applying chemical control, providing that they are not already full grown.

Potato Stem Borer

The larvae of the potato stem borer are light purple to pink in color and may reach 4 cm in length (Figure 21). The larvae burrow into the stalk of larger plants causing them to wilt, and die. Plants as tall as 40 cm may be affected. Since the larvae move from plant to plant, a section of row may show affected seedlings at all stages of damage. A larva can usually be found within the stem or in the soil near the base of the most recently attacked plant.

The adult of the potato stem borer is a brown moth that is active in August and September. Eggs are laid in grassy areas such as fence rows or weedy fields. The eggs hatch in the spring and the larvae begin to feed on grasses. As the larvae grow they seek out larger plants and move into the corn. Usually the damage is most severe near fencerows. However, damage can occur throughout the field, if grasses were not adequately controlled the previous year.

There is no effective chemical control for potato stem borer in corn. One can only make the area less attractive for egg-laying by controlling grassy weeds in the field and adjacent areas.

Figure 21. Potato stem borer larva

Cutworms

Cutworms of several species attack corn. They are smooth caterpillars that range in color from grey to dark brown to almost black (Figure 22). Cutworms usually damage corn by cutting off small plants at ground level or by tunnelling into the stalk, similar to the potato stem borer. Occasionally, they may feed on the leaves of small plants similar to armyworms.

Figure 22. Cutworm larva

Cutworm infestations are infrequent and unpredictable. Preventative treatments applied at planting times are not recommended. Reliable chemicals are available for controlling outbreaks after cutworms appear. Control is recommended if more than 5 percent of the plants show damage and the cutworms are still under 2.5 cm in length.

Corn Rootworms

Two species of rootworms damage corn in Ontario. The adult of the northern corn rootworm is a light green to greenish-yellow beetle about 5 mm in length (Figure 23). The Western corn rootworm is a slightly larger beetle that is yellow with black stripes (Figure 24).

Corn rootworms spend the fall, winter and spring as eggs in the soil. These eggs hatch in mid-June and the larvae move through the soil to the roots of nearby corn plants. The rootworms feed for 3-4 weeks, reaching full size in mid-July. They then form pupae in the soil, from which the adults emerge in early August. The adults feed on the silks of the corn and on the flowers of other plants for several weeks. Egg-laying begins in late August and continues until the adults are killed by frost. Eggs are laid in the soil near the base of corn plants.

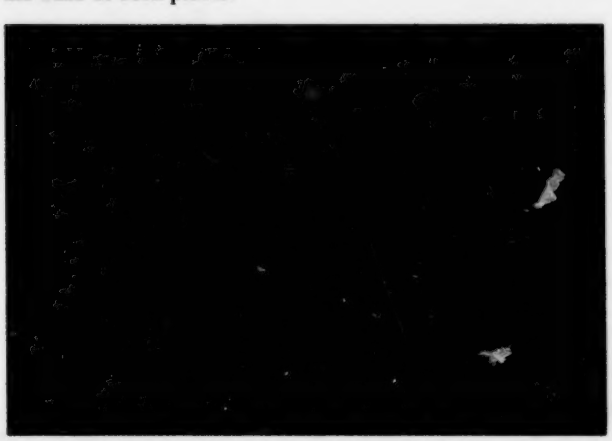

Figure 23. Northern corn rootworm adult

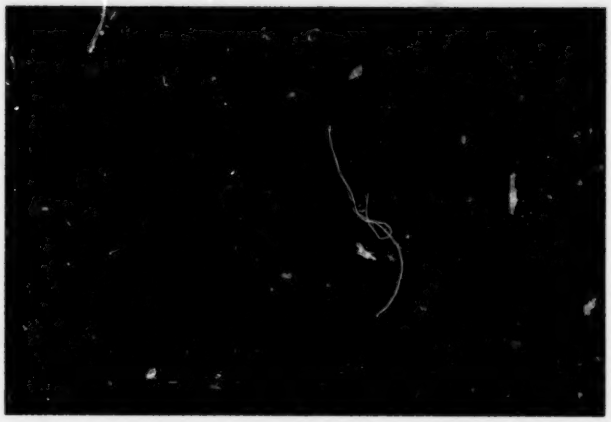

Figure 24. Western corn rootworm adult

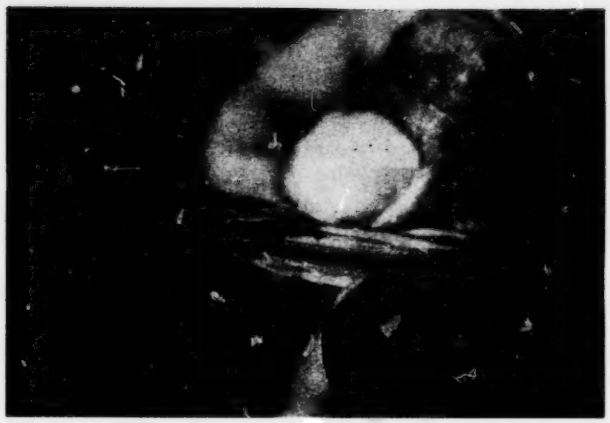

Figure 25. European corn borer larva

Most of the damage caused by rootworms is done by the larval stages feeding on the roots. Small roots may be completely consumed while larger roots are hollowed out or deeply gouged. With severe infestations, the entire root system can be almost destroyed.

Damage to the root system can result in a lack of vigor and reduced yield because of the interference with the uptake of water and nutrients. Also, heavy rain or wind can cause damaged plants to lodge. If this lodging occurs relatively early in the season, the plants may attempt to straighten up resulting in curved or "goose-necked" stalks.

Rootworm adults feed on corn silks and may completely clip them off. If the silks are removed prior to pollination, the ear may be partially or completely barren. Damage of this nature is relatively rare since field corn normally completes pollination before rootworm adults are present in significant numbers. However, damage at economic levels can occur in fields of late-planted or late-maturing corn. Rootworm adults are attracted to late fields as feeding sites, and are also likely to lay their eggs there. Thus, corn following a late-maturing corn crop is often at high risk of being damaged by larval feeding.

Since rootworm adults lay their eggs almost exclusively in corn fields, rotation with any other crop provides effective control of corn rootworms. Just one year of a crop other than corn is sufficient.

Where corn must follow corn in rootworm-prone areas, use of a soil insecticide applied at planting time is recommended.

European Corn Borer

Two strains of European corn borer are present in Ontario. The strain present in most of the province produces only one generation per year. However, in the area south of a line extending from Sarnia through London to Simcoe, there is also a strain which produces two generations per year.

The larvae are whitish in color with dark brown or black heads. Their backs are marked with rows of brown or black spots (Figure 25). The full-grown larvae overwinter inside the base of the corn stalk. In the spring, they form cocoons and begin the transformation into an adult. The adult moths usually emerge in early June and begin to lay their eggs shortly thereafter. Corn borer moths are cream-colored and are active at night. Eggs are usually laid on the underside of the leaves and hatch within 4 to 9 days. Young corn plants contain a chemical that repels corn borers. As the plants get larger, the concentration of this chemical decreases. Thus, the infestation of corn borers is often the heaviest in the most advanced fields in an area. This especially applies to the single generation strain of corn borer.

The newly hatched larvae usually move to the whorl where they feed on the developing leaves for a few days. Then they tunnel into the plant to feed within the tassel, stalk or ear shank. The damage caused by the larvae weakens the stalk making the plant more susceptible to stalk rots and lodging. Feeding damage in the ear shank can result in ear drop.

Chemical control measures for corn borer are rarely justified in field corn, and are difficult to time properly. Selection of hybrids with good standability is the best means of avoiding losses caused by corn borers. Any other measures which minimize the amount of stress suffered by the crop will also help reduce the effect of corn borer damage.

Corn Leaf Aphid

The corn leaf aphid is a green soft-bodied insect about the size of a pinhead. This insect does not overwinter in Ontario but is carried into the province each year on winds from the south. On corn, the aphids are usually found in the whorl and tassel. Aphid populations are usually highest during dry years. The amount of damage caused by aphids depends on the numbers present and moisture supply. In extremely dry years, severe infestations may cause large yield reductions. However, populations in excess of 300 to 400 per plant are usually needed to cause significant losses. While it is not uncommon to find scattered individual plants that are infested to this extent, widespread infestations at this level are rare.

Sap Beetles

Sap beetles (also called picnic beetles or beer beetles) are hard-shelled black beetles, about 6 mm long, with two yellow spots on each wing cover. They are frequently found in the whorls of plants that have been damaged by armyworms or corn borers and in the tips of ears damaged by rootworm adults, corn borers, birds or corn earworms. Sap beetles feed primarily on damaged tissue but do little damage themselves.

Corn Earworms

The larvae of the corn earworm range in color from green to brown. They reach a maximum length of 4 cm. Earworms feed on the silks and developing kernels near the tip of the ear. They do little direct damage themselves, but do expose the tip of the ear to invasion by other insects or diseases.

Other Corn Troubles

Bird Damage

Birds can damage emerging seedlings. However, the more serious damage occurs to grain in August and September. Birds eat the kernels off the cob causing direct yield loss, and kernel damage may result in mold growth. Feeding usually starts on exposed ear tips but with continued feeding the birds may shred the husks and damage several inches of the ear. Bird damage is more serious on corn close to large roosting areas. Red-winged blackbirds cause the most destruction, but grackles and starlings may also cause damage. Bird-scaring devices such as bangers may be successful deterrents.

Herbicide Damage

Chemicals that are recommended for corn may cause damage. Damage can take the form of abnormal color, twisted or thickened roots and shoots, or death. To avoid problems, follow the label recommendations.

Water Stress

Lack of water causes the leaves to wilt (Figure 26) and the plant to develop a grayish color. Water stress just prior to, at, or just following pollen shed is most detrimental to grain yield.

Hail

Hail can cause severe damage to corn by shredding the leaves. In extreme cases it can almost completely destroy the plant. If shredded leaves remain green, yield reductions will not be large.

Figure 26. Drought stress

Frost

Frost is most damaging when it occurs during the grain-filling period. The result is reduced yield, low test weight and a tendency to higher than normal lodging.

A frost after corn emergence in the spring usually does little damage. It will result in leaf death but new leaf material will quickly appear provided the growing point is not damaged.

CORN AS A GRAIN CROP

Corn is the largest and most valuable grain crop in Ontario. Of the approximately 5.5 million tonnes of grain produced in Ontario each year 40% is fed directly on the farm, 30% is exported out of the province, 15% is used by feed manufacturers and the remainder goes for industrial use (distillers, cereal, sugar, etc.).

Grain Corn Quality

Standards of quality for corn vary considerably depending on the needs of the buyer. All users of corn must be conscious of quality because damage reduces its storage life and can affect its usefulness, even as feed.

Corn is graded according to a system established by the Canadian Grain Commission (table 7). Many buyers purchase corn on the basis of its grade alone. Most industrial users require No. 2 corn but breakfast cereal manufacturers require less than 10% stress-cracked kernels.

Grain Corn — Harvesting Systems

The choice of a grain corn harvesting and handling system will be influenced by many factors: possible uses of the corn, amount of corn, capital cost, operating costs, time available for harvest and labor requirements.

Corn Picker — Crib Storage

Crib storage of ear corn can offer several advantages. Crib-dried corn is usually of superior quality and can meet the standards for the highest quality markets (for example, breakfast cereal manufacturers). Crib drying is a low-energy system, and therefore, operating costs are low, except for labor. Crib storage also retains the cob for use as feed or bedding.

Crib storage of corn is probably best suited to situations where relatively small amounts of corn are being stored or where a high-quality product is required. The amount of corn that can be handled by this system is restricted by the limited capacity of corn pickers and by the high requirement for labor in loading and unloading the crib.

Corn that is to be stored in a crib should be harvested at grain moisture contents of 26 to 30 percent. Corn that is put into a crib at grain moisture contents greater than 30 percent will likely spoil. Even at lower moisture contents, spoilage can occur if the crib is filled when the temperature is too warm. Harvesting should be delayed until the risk of prolonged warm temperatures is reduced but allowing the corn to get too dry before picking will increase harvest losses.

Proper design, location and construction of the crib is essential for long-term success of the system. The foundation must be built to resist the effects of frost, rot and rodents.

Table 7. Corn Grades
The class name, whether Yellow, White or Mixed Corn shall be added to and become part of the grade name.

Grade Name No.	Standard of Quality		Maximum Limits of *		
	Minimum Test Weight Kilograms per Hectoliter	Degree of Soundness	Damaged Corn		Cracked Kernels and other foreign material %
			Heated and Rotted Damaged %	Total Damaged %	
No. 1 Canada Eastern	68	Cool and Sweet and uniform in size	About 0.1	3	About 2
No. 2 Canada Eastern	66	Cool and Sweet	About 0.2	5	3
No. 3 Canada Eastern	64	Cool and Sweet	About 0.5	7	5
No. 4 Canada Eastern	62	Cool and Sweet	About 1.0	10	7
No. 5 Canada Eastern	58	Cool, may have slight odor, but not sour or musty	3.0	15	12
Sample		Fails to meet standards for No. 5			

* *Expressed as a percentage of the mass of the sample. Based on a visual separation of a 200 to 600 gram sample.*
— *"Heat damaged corn" consists of whole kernels or pieces of kernels that are discolored by natural fermentation, scorched by artificial drying, or rotted kernels.*
— *"Total damaged corn" consists of whole kernels or pieces of kernels that are sprouted, heated, frosted, moldy, grinding damaged, weather, or otherwise distinctly damaged. This damage must be plainly apparent.*
— *"Cracked kernels and foreign material" includes all material that passes through a number 12 round-hole sieve plus all foreign material remaining in the sample after screening. Seeds of other crops are considered as foreign material.*

Cribs should be located in open areas to ensure adequate movement of air through the corn. Cribs should be 1.25 to 2 m in width. Allow 3 cubic metres of storage space for each tonne of grain corn equivalent to be stored (2.5 cu ft/bu). The addition of a roof increases the cost considerably, but does prevent spoilage of grain at the top of the crib. Consideration should also be given to designs which reduce the labor required for unloading. Plans for corn cribs from the Canadian Farm Building Plan Service are available at local offices of the Ontario Ministry of Agriculture and Food.

Combine or Picker-Sheller Systems

Both of these harvesting methods deliver shelled corn at high moisture contents. Harvesting at grain moisture contents of 25 to 28 percent usually offers the best compromise between harvest losses and kernel damage. Corn harvested at 30 percent moisture or higher is almost always damaged to the point of being unacceptable for industrial use. The fines created in the grain also increase the risk of spoilage during storage.

When corn is harvested with a combine, damaged corn can result from any of the following: (a) cylinder speed too fast; (b) concave clearance too narrow; (c) too many concave filler bars; and (d) concave and cylinder not parallel. The owners' manual describes the adjustments necessary for proper operation with minimal damage to the corn. Be sure to adjust settings as changes in weather and crop conditions dictate. Regular checking of the harvested corn is essential to the production of high quality.

Several manufacturers are now marketing combines with either single or double rotary threshing units. Studies have shown that corn harvested by either rotary or conventional rasp-bar-cylinder units, has similar quality and losses, when the combines are adjusted according to the manufacturer's directions. (For information on determining corn harvest losses, see OMAF Factsheet, *Measuring Corn Harvest Losses*, Agdex 111/745.)

Grain Drying

Corn dries as the moisture it contains is evaporated from the kernel surface. At the start of the drying process, the heated air removes moisture located near the kernel surface. These first few percentage points of moisture can be removed quickly and with relatively little use of energy. As the kernel dries, moisture must be drawn from progressively greater depths within the kernel. In high-temperature dryers, moisture cannot move from the interior of the kernel to the surface as quickly as it is being evaporated. The outer layers of the kernel become extremely dry while the center remains wet. Once the outer part of the kernel becomes dry, the hot air flowing through the corn collects only a small fraction of the moisture that it could otherwise remove. Thus fuel is used inefficiently, in the final stages of drying in a high-temperature unit (i.e. after the corn has been dried to 18 to 20% moisture).

There are three main types of high-temperature dryers: (a) portable batch dryers; (b) in-bin dryers; and (c) continuous-flow dryers. When large amounts of grain are handled, continuous-flow dryers are usually used because of their higher capacity and ease of automation. (Refer to OMAF Factsheet, *Guide to Grain Dryers*, Agdex 110/736.)

Many dryer designs use a "cross-current" airflow which directs the hot air at right angles to the column of grain. This type of design often results in overheating and overdrying of the grain closest to the hot air plenum. Other dryer designs have incorporated concurrent airflow (parallel to the grain flow). Concurrent-flow dryers appear to offer advantages in terms of improved grain quality and energy efficiency.

Kernel Damage During Drying

The high temperature reached by corn in some dryers is responsible for much of the kernel damage that occurs

during drying. This damage can be either chemical or physical in nature. Either type of damage can make the corn unsuitable for industrial processing and therefore of lower value.

Chemical Damage

If corn kernels reach too high a temperature, chemical changes in the starch cause it to become gummy and to bind with the protein in the kernel. This reduces the suitability of the grain for many uses (Table 8). For example, separation of the starch from the rest of the kernel during milling becomes more difficult.

The critical temperature for chemical damage depends on the corn moisture at harvest. Below 24% moisture, corn can reach temperatures up to 80° C without significant damage. Corn harvested at 28% moisture should not be heated over 70° C if it is to be used for milling. If the corn is over 32% moisture, chemical change occurs only at 55° C.

In high-temperature, cross-current dryers, kernels on the inlet side of the column almost always reach the same temperature as the hot air plenum. These kernels will be over-dried and heat-damaged if plenum temperatures are too high. Continuous-flow dryers require a plenum temperature of at least 80°C to operate efficiently. Rather than reduce the dryer temperature, it is more effective to reduce heat damage by using dryeration or by adding a steeping or a transition section to the dryer.

Table 8. Critical maximum temperature for drying of grain corn harvested at 28% moisture.

Intended Use	Maximum temperature* (°C)
Seed	45°C
Starch milling	70
Other industrial uses, non-ruminant feed	90
Cattle feed	120

**Refers to maximum temperature reached by all or a portion of the grain. In cross-current and in-bin dryers, this usually corresponds to the hot air plenum temperature.*

Stress Cracks

Stress-cracked kernels are broken kernels held together by only a thin pericarp which surrounds the kernel. Although stress-cracked kernels may hold together long enough to grade well upon initial inspection, the pericarp is easily ruptured during handling. Severe stress-cracking can make corn unsuitable for industrial users and may limit the export opportunities for Ontario corn.

Stress cracks result mainly from rapid cooling of hot corn. When hot grain is cooled rapidly, which happens in most continuous-flow dryers, the outer layers of the kernel become cool while the center remains hot. The resulting stresses cause the kernel to break. If corn is intended for industrial or export markets, consideration should be given to systems which reduce stress cracking. These include dryeration, low-temperature drying and combination high-low temperature systems.

Dryeration

In many dryeration systems, the cooling portion of the dryer (or the cooling cycle in batch dryers) is eliminated. When it has reached 16 to 18% moisture the corn is transferred hot into a small dryeration bin. Here it is "tempered" or allowed to sit without aeration for 6 to 12 hours. Then it is cooled for an additional 6 to 12 hours at a ventilation rate of 9.0 to 18 litres per second per tonne of corn (.5 to 1 cu ft/min/bu). This is 5 to 7.5 times the ventilation rate used in conventional aeration systems.

When hot corn is removed from a dryer, most of the moisture is in the center of the kernel. During tempering, this moisture diffuses outward until it is distributed uniformly throughout the kernel. This tempering process allows the removal of 2 or 3 additional percentage points of moisture during cooling using only the heat stored in the corn. Because the corn is cooled slowly stress cracking is eliminated.

Dryeration results in: (1) improved grain quality; (2) more efficient use of energy; and (3) increased dryer capacity. Against these benefits one must weigh the increased capital cost of the system and the extra handling of the corn. In many systems corn is tempered and cooled in batches, so that two dryeration bins are needed if the dryer is run continuously.

In many dryeration systems, corn is moved from the dryeration bin to a different bin for storage. However, corn can be successfully stored in the dryeration bin if it is aerated thoroughly to remove all excess moisture and heat. Otherwise, condensation on the bin walls can present a storage hazard.

Low Temperature Drying

In low-temperature drying, the corn is dried with unheated, or slightly heated air until it is dry and cool enough for long-term storage. This drying takes place over a period of several weeks or months. In some cases, the corn may not be dried enough to store safely beyond the winter. Additional aeration in the spring may be necessary to complete the drying process unless the corn can be sold or fed before the weather warms up.

Low-temperature drying is a race between the rate of drying and the rate of grain deterioration due to mold growth. Since mold growth becomes more rapid as temperature and corn moisture increase, low temperature drying should not be used for corn over 24% moisture. The average outside air temperature should be under 10° C (average of daily maximum and minimum temperature). Corn at 20% moisture needs an airflow rate of 20 litres/sec/tonne (1 cu ft/min/bu) but the rate should be doubled for corn at 24% moisture. The airflow can be increased by increasing the fan output or by reducing the depth of corn. Because of the extra power required to increase fan output, it is easier and more economical to reduce the depth of corn.

Low temperature drying completely eliminates damage from over-heating and stress cracks. It seems well suited for economically producing quality corn where 400 tonnes or less are to be dried, although it has been used for much larger quantities. The major drawback is that most farms do not have the electrical power to handle large low-temperature dryers.

Careful management is essential to ensure that drying is completed before mold damage occurs. In particular the corn must be clean and free from damage to ensure uniform movement of air.

Combination Systems

Many variations and combinations of the above systems are possible. One of the more widely used is a high-temperature start, combined with a low-temperature finish, also called "cooleration". In this system wet corn is dried quickly to approximately 20 to 24% moisture in a high-temperature dryer. Then it is transferred hot to a storage bin where cooling and drying are completed using aeration at low temperature drying airflow rates. This system offers most of the benefits of dryeration without the extra investment and handling, while reducing risk of spoilage in the low-temperature part of the process.

Overdrying

Corn is priced on the basis of a moisture content of 15.5%. Because there is no price adjustment for corn at lower moistures, the marketing of overdried corn creates a loss of potential income to the producer. For example, drying corn to 13.5% instead of 15.5% removes an extra 23 kg of water per tonne of grain. Thus, the amount of grain corn to be marketed is reduced by 2.3%. In addition, energy is wasted in this unnecessary drying; dryer capacity is reduced and the corn becomes more subject to breakage during handling. Corn should be dried no more than is necessary to ensure safe storage for the desired length of time.

Grain Corn Storage

Corn must be stored in a manner that will preserve its quality regardless of whether it is kept for a livestock feed or for sale to industrial users. Cash crop corn can be sold immediately at harvest, but storage of the corn for later marketing can be advantageous. Storage allows the corn grower to take advantage of price changes throughout the year avoiding the lower prices of the harvest season. On-farm storage also offers greater flexibility in the choice of markets. However, storage adds to the cost of corn production through increased overhead or capital costs, drying and handling costs and interest charges.

Corn in storage deteriorates as it is attacked by molds or insects. The storage life of corn depends mainly on its moisture content and temperature. Corn stored at a low moisture content and low temperature will keep almost indefinitely. As either the moisture content or temperature is increased, the length of the storage period is reduced (Figure 27). Because of the low temperatures during winter in Ontario, corn can be stored safely at 15% moisture over the winter and spring if aerated properly. Longer periods of storage will require that the grain be slightly drier. Refer to Table 9 for moisture guidelines.

Table 9. Moisture guidelines for safe storage of corn

Storage period	Desirable moisture content
Harvest to late spring	15-16%
To late summer	13-14%
Several years	11-13%

Aeration

One of the biggest problems in stored grain is the migration of moisture through the grain mass because of temperature differences within the grain (Figure 28). This occurs most often when the difference in temperature between the grain

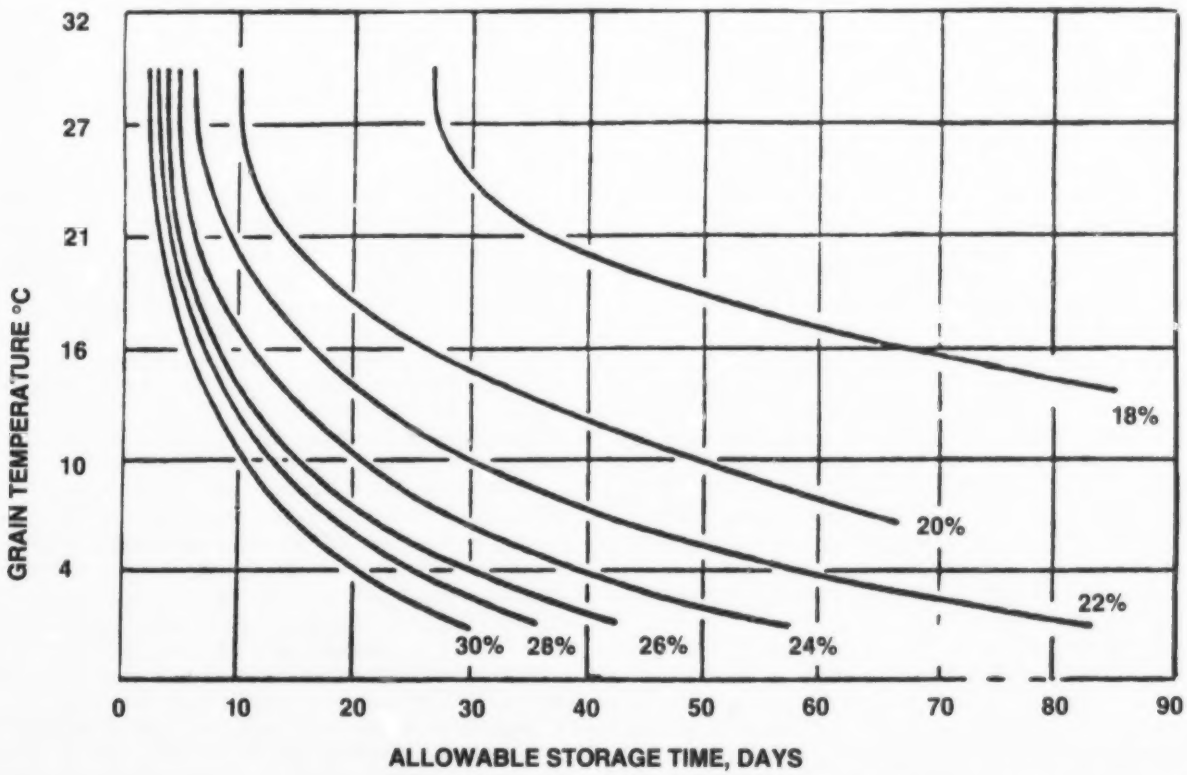

Figure 27. Effect of temperature and moisture content on safe storage life of corn

(Data are from the U.S. Department of Agriculture Grain Storage Research Laboratory, Ames, Iowa). Broken kernels may mould more than 5 times as fast.

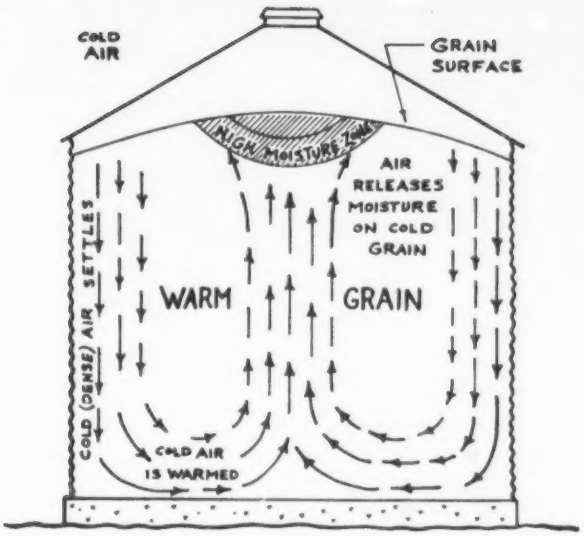

Figure 28. Moisture migration patterns in stored grain

mass and the outside air is greater than 10 to 12° C. Moisture migration results in condensation of moisture and spoilage in pockets of corn. Grain masses under 25 t usually cool uniformly, but larger amounts require aeration. Usually an airflow rate of 1.8 litre per second per tonne (0.1 cu ft/min/bu) of grain is sufficient.

Aeration should begin as soon as the corn is put into storage and continue periodically until the grain has reached a safe storage temperature (less than 3° C). This cooling should be done in steps of 3 to 5° C as outside temperatures fall. For each step, aerate until the air coming out of the grain is the same temperature as the outside air. This will ensure that all of the grain has been cooled. Aerate as needed to keep the grain mass within 10° C of the average outside air temperature.

During the winter, corn can be kept safely at 0 to 3° C, but should be checked weekly for temperature changes and the presence of hot spots. Run the fan briefly and record the temperature of the air coming out of the bin. Note any unusual odors. Compare the results against previous readings to see if any problems are developing. Under some conditions, it may be necessary to aerate during the winter to re-establish a uniform temperature within the corn.

In the spring, the corn should be aerated to warm it up slowly. This should also be done in steps, keeping the grain temperature within 10°C of the average outside temperature. Warming the grain should begin in March. Aerate on cool, dry days to reduce condensation. Never draw warm, moist air through cold grain because the resulting condensation will cause spoilage. (Refer to OMAF Factsheet, *Grain Aeration*, Agdex 110/717.)

Prevention of Grain Spoilage

Damage from molds can be prevented by proper drying and aeration of the corn as outlined above. However, considerable damage can also be caused by insect infestations which can occur in dry corn. Insects are present in most grain-handling systems and it is almost impossible to eliminate them completely. However, loss from insect damage can be kept to a minimum by using the following program.

1. Remove all dust and old grain from bin walls, ceilings, floor and aeration ducts before refilling the bin.
2. Repair cracks where insects might enter.
3. Spray inside the bin with a residual insecticide at least one week before storing new grain.
4. Never store new corn on top of old since insects will move from the old grain into the new.
5. Cool grain as quickly as possible. Insects cannot reproduce at temperatures below 18°C.
6. Check stored grain regularly to detect hot spots.
7. Employ aeration and/or cold weather transfers to reduce temperatures.
8. Fumigate difficult insect infestations.

For more detailed information see OMAF Publication 229, *Insects in Farm-Stored Grain.*

HIGH MOISTURE CORN

High moisture corn can be stored as whole shelled, ground corn or ground ear corn. It is an attractive alternative to dry corn systems, because of the savings in time and money through elimination of drying. But it cannot be readily marketed and is mainly a livestock feed.

The average nutrient content of dry shelled and high moisture corn is listed in Table 10.

Table 10. Average composition of dry shelled corn, high-moisture grain corn (HMC) and high moisture ear corn (HMEC)

	Percent (%) on an as-fed basis		
	Dry Shelled Corn	**HMC**	**HMEC**
Dry matter	85.0	72.0	72.0
Crude protein	8.7	7.3	6.2
Digestible protein	6.7	5.6	4.5
Total digestible nutrients	80.1	67.3	61.2
Fat	3.9	3.3	2.7
Fibre	2.0	1.7	6.7
Calcium	0.02	0.02	0.03
Phosphorus	0.27	0.23	0.18

High moisture corn is stored at moisture contents ranging from 20 to 35%, with the optimum on most farms being 25 to 32%. For moisture contents below 25% only an oxygen-limiting silo (also known as a "sealed silo") should be used. At moistures above 32% shelling and flowability are hurt and the crop is best harvested and stored as ground ear corn.

Whole-Kernel Corn

Whole-kernel corn does not pack in the silo as well as ground corn. Although it can be stored in any type of silo, it is most easily stored in oxygen-limiting silos. In open-top silos, whole-kernel corn should be ensiled at a moisture content of 25 to 30%. In oxygen-limiting silos, corn as low as 22% moisture can be stored safely. Whole-kernel corn should be cracked or rolled before feeding to improve feed efficiency.

Ground Shelled Corn

Where high-moisture shelled corn must be stored in an open-top silo, the risk of spoilage is reduced if the grain is ground before ensiling. It should be ground so that every kernel is cracked into three to five pieces. It should be at a moisture content of 24 to 30%.

Ground Ear Corn

Ground ear corn is an excellent feed for cattle because the animals are able to use much of the feed value in the corncob. Ground ear corn should be ensiled at a grain moisture content of 25 to 30%. (Moisture content of the whole ear will be four or five percentage points higher than that of the grain.) The ear must be ground so that most of the kernels are cracked and there are no pieces of cob larger than 2 cm in diameter. The finer the material is ground, the better it will pack in the silo and the lower the risk of spoilage. However, over-grinding must be avoided as this can create problems with palatability and animal performance.

Ear corn can be ground using recutter screens on the forage harvester or blower, or by processing through a separate machine such as a hammer mill. Grinding the corn is often the slowest step in harvesting ground ear corn.

Storage

High-moisture corn can be successfully stored in any type of silo. No matter what system is used, care has to be taken to ensure high-quality feed with a minimum of problems. Holes or cracks that allow air to enter should be repaired.

Use of a distributor with upright silos is essential, particularly if ensiling ground material. With open-top and horizontal silos at least 5 cm of material should be removed daily. During warm weather it may be necessary to remove 8 - 10 cm daily.

Open-top silos should have a roof to keep out rain and snow, be free of cracks and have the doors sealed tightly.

Because high-moisture corn exerts considerable pressure on silo walls, the silo should be in good shape prior to filling. If the inner surface of the silo is soft or porous, it should be refinished. Another option is the use of heavy plastic bags or inserts used in combination with bottom unloading, but this option is not recommended for silos larger than 5 m (16 ft).

Oxygen-limiting silos should be checked for leaks and all doors must be tightly sealed when not in use. When filling it is advisable to run out 200 - 300 litres (5 - 10 bu) after each load. This helps to establish flow patterns which will reduce bridging when feeding out.

Horizontal silos should be covered with a heavy plastic sheet, weighted down for a tight fit.

CORN SILAGE

Whole-plant corn silage is Ontario's most commonly grown, high-yielding energy forage. Corn for silage is ideally suited to mechanization from planting to harvest and complements a hay crop silage system.

The average nutrient content of whole-plant corn silage is listed in Table 11.

Table 11. Average composition and digestible nutrients of whole-plant corn silage.

	Percent (%) on an as-fed basis
Dry matter	27.6
Crude protein	2.3
Digestible protein	1.2
Total digestible nutrients	18.3
Fat	0.8
Fibre	6.7
Calcium	0.10
Phosphorus	0.07

Silo Selection

Upright (tower), open-top concrete silos are the most common type of storage in Ontario. Well-managed, open-top silos of poured concrete or concrete staves make excellent silage with losses averaging about 10% of the total dry matter stored. Higher losses can be expected under conditions of poor management. Removal of 5 cm per day in the winter and 7 cm per day in the summer is usually sufficient to keep surface spoilage to a minimum.

Where large amounts of silage are being stored, horizontal silos become practical. Storage losses in horizontal silos average about 15% of total dry matter stored.

The Ensiling Process

When freshly cut corn is put into a silo the plant cells continue to breath using up oxygen and giving off carbon dioxide. At the same time, yeasts and molds begin to act on the silage. These also require oxygen and give off carbon dioxide. If the silage mass is compacted and the silo is properly sealed to prevent further entry of air, respiration losses are minimized. With proper management, air trapped in the silage mass is used up approximately 48 hours after sealing. Once this trapped air is used, anaerobic fermentation by bacteria begins. These bacteria produce lactic acid which lowers the pH of the silage, in essence pickling the plant material and preventing further spoilage.

Respiration losses will increase if the silo is not filled quickly and sealed properly, or if the silage is not well-packed. The continued presence of air in the silage mass allows molds and yeasts to thrive and multiply resulting in heating. Excessive heating causes a reduction in protein and energy digestibility.

Once air is finally excluded from the silo, molds and yeasts become dormant. However, as soon as the silage is unloaded from the silo and air is reintroduced, they become active again. If present in large numbers, they can quickly cause spoilage of the feed. Harvesting when too dry, downtime at harvest or poor silo management can markedly reduce the bunk life of any silage.

Harvesting and Storage of Silage

The feed quality of corn does not change with advancing maturity. However, as the crop matures it dries down and this becomes the important consideration in deciding when to harvest. For tower silos, corn silage should be harvested between 60 and 70% moisture. At moisture levels greater than 70%, seepage from the silo is likely to occur. If the corn is ensiled too dry, packing may not take place increasing the risk of mold growth and heat damage. Moisture contents generally need to be higher for horizontal silos to achieve good compaction.

Table 12. Moisture range at ensiling various silo types and sizes.

Silo Type	Moisture Range Recommended
Tower	
Small (3.6 m x 10.5 m)	65 - 70%
Medium (6 m x 18 m)	60 - 65%
Large (9 m x 30 m)	60 - 65%
Horizontal	65 - 72%

Compaction of the forage requires a considerable height of material to provide the weight necessary to expel air from the mass. Therefore, the upper portion will be less dense and hold more air permitting heating. Material in the upper third of the silo should contain 65 to 70% moisture to get a better pack.

Fine chopping helps to exclude air because packing is tighter. Length of cut is most critical for horizontal silos. Harvester blades must be sharp and set correctly. Badly worn ledger bars should be replaced. A theoretical length of cut of 6 to 10 mm is desirable with 65% moisture silage and is essential with silage containing less than 60% moisture. Chopping finer than 6 mm is not advisable.

Provide a tight silo. A silo acts like a chimney. Air entering near the bottom is drawn up through the silage resulting in excessive heating and spoilage. The walls and doors of new silos are usually airtight. However, older silos may have air leaks in the walls or around the doors. These should be reconditioned and/or caulked and sealed. Even in sealed silos, air will penetrate the silage mass when the filling port is left open or when the unloading door is opened for feeding.

Even distribution of the silage during filling is necessary to avoid separation of the light from heavier material. Light material tends to land next to the wall, preventing good packing. In a few cases poor distribution of material has caused the silo to collapse.

Fill the silo rapidly — continuously if possible. If filling is delayed over several days, the upper layer of each filling will be noticeably poorer in quality. Sealing the silo during downtime will help to reduce this effect.

Seal the silo. In airtight silos the door should be closed as soon as silo filling is complete. In open-top tower silos, the silage should be levelled and sealed with plastic if it is not to be fed out immediately. Sealing with plastic is essential on horizontal silos. The plastic should be adequately secured and weighted down. If allowed to flap, the plastic cover can act like a bellows by forcing air into the silage mass.

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OMAF Factsheets

Agdex Number	Title
100/536	*Tillage Practices for Residue Management and Erosion Control*
100/531	*Zinc Requirements for Field Crops*
100/732	*Farm Silo Selection*
100/732	*How to Buy a Farm Silo*
100/622	*Armyworm*
100/717	*Grain Aeration*
110/736	*Guide to Grain Dryers*
111/25	*Corn Lodging*
111/31	*Heat Units for Corn in Southern Ontario*
111/61	*High Moisture Corn*
111/541	*Nitrogen Recommendations for Corn*
111/542	*Nitrogen Fertilizer Materials*
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111/622	*Potato Stem Borer in Ontario*
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111/730	*Grain Handling Systems*
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111/745	*Measuring Corn Harvesting Losses*
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